Shunyaya Structural Buoyancy (SSB)

When Floating Is No Longer Enough

Status: Foundational Research Release (v2.1)
Date: February 06, 2026
Caution: Research and observation only. Not for critical or automated decision-making.

---

0. Executive Structural Summary

Shunyaya Structural Buoyancy (SSB) is a deterministic governance framework that operates **above classical buoyancy** to determine whether a floating state may be **safely trusted for operation**.

Classical buoyancy laws — including Archimedes' principle — determine whether an object floats.
They do **not** determine whether that floating state should be relied upon over time, under disturbance, repetition, or degradation.

SSB introduces a structural admissibility layer that:

- preserves all classical physics unchanged
- never modifies forces, geometry, or equilibrium
- introduces no simulation, prediction, or probabilistic modeling
- governs **permission to operate**, not physical behavior

SSB formalizes buoyancy as a **governed state**, subject to:

- alignment margin
- accumulated structural resistance
- lifecycle exposure
- irreversible trust denial

Across deterministic validations, SSB consistently denies operational trust **before** classical instability occurs, without altering any physical equations.

This document presents:

- Phase I — formal governance logic
- Phase II — canonical deterministic validation
- Phase III — operational envelope classification
- Phase IV — standardization, positioning, and system generalization

SSB completes classical buoyancy by answering a previously unformalized question:

Not only “does it float?” — but “should this floating state be trusted?”

TABLE OF CONTENTS

0.1 — Public Contract Summary (Frozen Interface)

This subsection defines what is non-negotiable in SSB (the contract), and what is allowed to vary (declared thresholds), without changing the theory or implementation.

A) Invariants (mandatory — must never change)

Any implementation or derivative that violates any of the following invariants is not considered SSB.

1. Physics preservation (collapse invariant)
   SSB preserves classical hydrostatic correctness without alteration.
   If buoyant or stability truth is represented as a structural state `(m, a, s)`, then:

   ```
   phi((m, a, s)) = m
   ```

SSB may deny trust, but it must not modify classical outputs.

2. No prediction, simulation, or probability
   SSB does not simulate future states, predict failure timing, assign probabilities, or optimize risk.
   Outputs represent governance decisions about permission, not forecasts about outcomes.
3. Declared threshold discipline
   All thresholds must be declared before execution, remain immutable during execution, and be auditable after execution.
   SSB does not fit, learn, search, or tune thresholds during runtime.
4. Determinism and replayability
   For identical inputs and identical declared thresholds, SSB must produce identical outputs across re-runs, machines, and environments.
   No randomness, hidden state, or adaptive behavior is permitted.
5. Monotonic trust exhaustion and irreversibility of denial
   Within a lifecycle evaluation, accumulated resistance `s(t)` must be monotone non-decreasing by construction.
   Once SSB reaches DENY due to exhausted trust (for example `s(t) >= s_max` or `a(t) < a_min`), denial remains in force within that lifecycle unless an explicit external structural reset is performed.
   Later correctness must not restore permission automatically.
6. Conservative ordering relative to classical instability
   SSB must never allow operation when classical effective stability is non-positive.
   At minimum:
   if `GM_eff <= 0` → DENY
   SSB may deny earlier than classical instability, but must not deny later.

7. Safe default under invalid inputs
   If required inputs are missing, invalid, non-finite, or undefined, SSB must return:

   ABSTAIN_HUMAN_REVIEW
   ABSTAIN acts as a safety guardrail rather than an indeterminate state.

B) Declared parameters (allowed but frozen per run)

The following quantities are engineering or policy declarations made prior to execution. They are not learned, tuned, or optimized inside SSB.

- `GM_safe` — trust reference level
- `a_min` — minimum admissible alignment
- `r_safe` — local tolerance offset
- `s_max` — maximum admissible accumulated resistance
- `s_warn_frac` (Phase III only) where `s_warn = s_warn_frac * s_max`

C) Output states (fixed semantics)

SSB produces governance states. These are not probabilities and must not be interpreted as predictions.

- ALLOW_NORMAL — operation structurally admissible
- ALLOW_RESTRICTED_MONITOR — operation admissible with restrictions or monitoring
- DENY_FINAL — trust exhausted; reliance withdrawn even if physics remains correct
- ABSTAIN_HUMAN_REVIEW — inputs invalid or insufficient for automated permission

---

D) Summary guarantee

Classical values remain exact; structural permission becomes explicit and auditable.

0.2 Threshold Declaration and Justification Framework

SSB operates using declared thresholds rather than derived or optimized limits.
This is intentional. The purpose of SSB is not to discover optimal parameters, but to make the withdrawal of operational trust explicit under declared engineering assumptions.

This section provides guidance on how thresholds may be justified without altering the deterministic nature of SSB.

A) Principle of declared thresholds

Thresholds in SSB represent engineering or governance decisions external to the algorithm itself.

SSB therefore requires that:

- thresholds are declared before execution,
- thresholds remain fixed during execution,
- thresholds are auditable after execution,
- no internal adjustment or optimization is permitted.

SSB evaluates consequences of declared assumptions; it does not generate them.

B) Acceptable declaration approaches

The following approaches are considered structurally valid ways to declare thresholds. These approaches are non-binding and may be combined.

1) Consequence-based declaration

Thresholds may be chosen according to consequence severity.

Higher consequence assets or operations may use more conservative values, leading to earlier restriction or denial. Lower consequence environments may allow larger margins before trust withdrawal.

Example interpretation (illustrative only):

- passenger or high-density assets → conservative `a_min` and lower `s_max`
- low-risk operational assets → less conservative limits

SSB itself does not assign consequence levels; it only evaluates declared inputs.

---

2) Evidence-anchored declaration

Thresholds may be derived from:

- existing stability practice,
- inspection or maintenance regimes,
- historical degradation observations,
- operator or regulatory safety margins.

In this approach, SSB formalizes when accumulated exposure exceeds the declared tolerance of continued reliance.

---

3) Sensitivity sweep (documentation use only)

Organizations may execute multiple runs using different declared thresholds to understand how governance transitions move relative to exposure.

This process is informational only:

- SSB must not select a preferred threshold internally,
- no optimization loop is permitted,
- results are interpreted by engineers outside the system.

The purpose is transparency, not tuning.

C) Separation from classical limits

Declared thresholds do not replace classical stability requirements.

Classical limits determine physical correctness.
SSB thresholds determine when reliance on that correctness is no longer considered structurally trustworthy.

Thus:

- classical hydrostatics answers “is it stable now?”
- SSB answers “should continued reliance still be permitted?”

D) Governance interpretation

Different declared thresholds may produce earlier or later DENY outcomes. This is expected and reflects differing risk postures rather than algorithmic variability.

The deterministic guarantee remains unchanged:

for a fixed input history and fixed declared thresholds, SSB produces a single reproducible governance outcome.

0.2 Non-Negotiable Design Invariants (Mandatory)

This document defines **Shunyaya Structural Buoyancy (SSB)** as a **structural governance layer above classical buoyancy and stability**.
The invariants below are **mandatory**.
Any implementation or derivative that violates **any** invariant is **not SSB**.

I. Physics Preservation (Collapse Invariant)

SSB must preserve **classical hydrostatic correctness without alteration**.

Formally, if buoyant / stability truth is represented as a structural state `(m, a, s)`, then:

```
phi((m, a, s)) = m
```

Meaning:
Governance may **deny trust**, but it may **not change the classical output**.

II. No Prediction, No Simulation, No Probability

SSB must **not**:

- simulate futures
- predict failure timing
- assign probabilities
- infer likelihoods
- optimize risk

SSB outputs are **governance decisions about permission**, not forecasts about outcomes.

III. Declared Threshold Discipline (No Tuning During Execution)

All thresholds (e.g., `GM_safe`, `a_min`, `r_safe`, `s_max`) must be:

- **declared before a run**
- **immutable during a run**
- **auditable after a run**

SSB must **not** fit, learn, search, or tune thresholds **inside execution**.

IV. Determinism and Replayability

For **identical inputs** and **identical declared thresholds**, SSB must produce **identical outputs** across:

- re-runs
- machines
- environments

SSB must contain:

- **no randomness**
- **no hidden state**
- **no adaptive behavior**

V. Monotonic Trust Exhaustion and Irreversibility of DENY

Within a lifecycle evaluation, accumulated resistance `s(t)` must be **monotone non-decreasing by construction**.

Once SSB reaches **DENY** due to exhausted trust (e.g., `s(t) > s_max` or `a(t) < a_min`):

- denial is **irreversible within that lifecycle**
- unless an **explicit, external structural reset** is performed

Correctness at later times **must not restore permission**.

VI. Conservative Ordering Relative to Classical Instability

SSB must **never allow operation** when classical effective stability is non-positive.
At minimum:

- if `GM_eff <= 0`, SSB must output **DENY**

SSB **may deny earlier** than classical instability.
SSB **must not deny later** than classical instability.

VII. Safe Default: ABSTAIN Under Invalid Inputs

If required inputs are missing, invalid, non-finite, or undefined, SSB must default to **ABSTAIN** (human review), **not ALLOW**.

ABSTAIN is a safety guardrail, not indecision.

These invariants **define SSB**.
They exist to keep SSB:

- **conservative**
- **audit-grade**
- **deterministic**
- **structurally honest**

---

1. Introduction

The principle of buoyancy, formalized by Archimedes, is one of the most successful and universally accepted laws in physics. It precisely determines the upward force exerted on a body immersed in a fluid and explains why objects float or sink.

However, buoyancy answers only a narrow question:

Does the object float?

In real-world operation — ships, offshore platforms, floating bridges, rescue vessels — a more critical question exists:

Should this floating state be trusted?

Shunyaya Structural Buoyancy (SSB) introduces a structural layer above classical buoyancy that answers this missing question **without modifying, contradicting, or extending** Archimedes' law.

SSB does not alter physics.
It governs the structural admissibility of floating.

---

2. Retrospective Case Mapping (Empirical Anchoring)

SSB is not a predictive or probabilistic model.
Its purpose is to formalize when operational reliance should be withdrawn under accumulated exposure, even while classical stability remains positive.

This section provides retrospective mappings to well-documented incident classes in order to demonstrate how SSB interprets delayed-failure scenarios. These examples are illustrative and conceptual. They do not reconstruct incidents numerically and do not claim prediction capability.

The objective is to show how SSB separates physical correctness from continued structural trust.

2.1 General pattern of delayed failure

Many equilibrium-based systems fail after extended periods during which classical checks remain nominally acceptable. In marine and offshore contexts this often appears as:

- positive or marginally acceptable stability values,
- repeated operational disturbances,
- gradual degradation or accumulation of exposure,
- sudden loss of admissible operating margin.

Classical hydrostatics answers whether the system is stable at a given moment.
SSB evaluates whether accumulated exposure has exhausted the admissible basis for continued reliance.

Conceptually:

- classical stability evaluates instantaneous state,
- SSB evaluates lifecycle trust exhaustion.

2.2 Representative case class A — repeated disturbance with delayed loss of margin

In several historical ferry and passenger vessel incidents, stability remained technically positive until shortly before loss of control. However, operational exposure accumulated through repeated disturbance factors such as loading variations, free-surface effects, or operational deviations.

Under an SSB interpretation:

- `GM_eff` may remain positive,
- alignment `a(t)` gradually decreases as margins approach declared limits,
- resistance accumulation `s(t)` increases due to repeated exposure beyond the declared tolerance `r_safe`.

SSB governance would therefore tend to transition through:

ALLOW_NORMAL → ALLOW_RESTRICTED_MONITOR → DENY_FINAL

before classical instability necessarily occurs.

The key distinction is that denial arises from exhausted structural trust rather than immediate physical instability.

2.3 Representative case class B — prolonged operational exposure in offshore assets

Floating production and offshore assets may remain physically stable over long periods while experiencing cyclic environmental loading, fatigue exposure, or operational envelope drift.

In classical evaluation:

- instantaneous stability checks may remain acceptable.

Under SSB interpretation:

- repeated exposure increments resistance accumulation,
- `s(t)` increases monotonically,
- governance denial may occur while physical stability remains technically positive.

This represents withdrawal of reliance due to lifecycle exhaustion rather than imminent capsize.

2.4 Representative case class C — accumulation without visible degradation

Certain failures occur after long periods without visible structural warning because each individual disturbance remains within acceptable limits. The failure mechanism emerges from accumulation rather than from any single event.

SSB formalizes this class explicitly:

```
s(t+1) = s(t) + max(0, r(t) - r_safe)
```

Even small repeated deviations beyond declared tolerance accumulate deterministically until admissibility is exhausted.

This makes delayed failure structurally observable without requiring probabilistic modeling.

2.5 Interpretation boundaries

The retrospective mappings in this section are intentionally conservative.

SSB does not:

- predict incident timing,
- reconstruct accident sequences,
- assign causality,

- replace investigation findings.

Instead, SSB demonstrates that many delayed failures share a common structural pattern: continued reliance after accumulated exposure has exceeded declared tolerance.

SSB converts that implicit judgment into an explicit and auditable governance state.

---

3. Classical Buoyancy (Unchanged Baseline)

Classical buoyancy states:

```
F_b = rho_fluid * g * V_displaced
```

Where:

- `F_b` = buoyant force
- `rho_fluid` = fluid density
- `g` = gravitational acceleration
- `V_displaced` = displaced fluid volume

This equation is necessary and sufficient to determine vertical force equilibrium.

However, it is structurally silent about:

- stability margin under disturbance
- drift accumulation
- oscillatory fatigue and repetition effects
- delayed instability after long apparent safety
- **trustworthiness of equilibrium for operations**

SSB operates entirely above this equation.
Archimedes remains the baseline; SSB governs whether baseline buoyancy may be relied upon.

---

4. Structural Reframing

Floating as a Negotiated State

SSB introduces the idea that floating is not merely a binary outcome, but a negotiated structural truce between:

- gravity
- geometry
- alignment
- history (accumulated exposure)

Two objects may float at the same waterline with identical buoyant force, yet exhibit radically different structural behavior over time.

In SSB:

Floating is not merely force balance.
Floating is structural posture under disturbance.

This reframing is conservative: it does not change the physical truth of buoyancy — it makes the structural truth of reliance observable.

---

5. SSB Across the Five Shunyaya Framework Layers

5.1 SSOM — Structural Origin of Floating

At origin, a floating system is represented as:

```
(m, a, s)
```

Where:

- `m` = classical buoyant equilibrium (unchanged classical truth)
- `a` = alignment between mass distribution and displacement geometry
- `s` = latent structural stress at origin (pre-existing fragility)

SSOM distinguishes between:

- **earned equilibrium** (low latent stress, high alignment margin)
- **accidental equilibrium** (high latent stress, marginal alignment)

Classical buoyancy does not make this distinction.

5.2 SSM — Symbolic Posture of Buoyancy

SSM treats buoyancy as a posture, not just a force.

Symbolically:

```
phi((F_b, a)) = F_b
```

The force remains invariant, but posture may drift.

This makes it possible to represent a core operational reality:

Two bodies can share the same `F_b`, yet differ sharply in **trust**, because their structural posture differs.

5.3 SSUM — Structural Evolution Over Time

SSUM models floating as a time-evolving structural process:

```
(m, a, s)_(t+1) = evolve((m, a, s)_t)
```

SSUM captures:

- accumulation of tilt stress under repeated exposure
- wave-induced fatigue without requiring simulation
- asymmetric restoring degradation (posture erosion)
- delayed instability after long periods of apparent safety

This explains why many floating failures occur **after** long durations of “still floating.”

5.4 SSD — Structural Diagnosis of Floating Risk

SSD performs non-predictive structural diagnosis. It does not attempt to forecast waves or future states. It simply diagnoses whether the current posture remains safe to rely upon.

SSD can:

- identify erosion of restoring margins
- detect repeated exposure accumulation
- flag unsafe reliance even when floating persists

SSD may conclude:

“Floating is classically correct, but structurally unsafe to rely upon.”

This diagnostic outcome has no equivalent in classical buoyancy theory, because classical buoyancy is not a governance layer.

5.5 SSE — Structural Governance of Buoyancy

SSE governs whether buoyancy should be trusted operationally:

- `ALLOW(F_b)`
- `DENY(F_b)`

- `ABSTAIN(F_b)`

The object may still float physically, but systems are instructed **not** to depend on the floating state when denied.

This is governance, not prediction.
SSB is therefore not a new buoyancy law — it is a structural trust governor over an unchanged buoyancy law.

---

6. Formal Mapping to Metacentric Height (GM)

6.1 Classical Stability (Unchanged)

Metacentric height is the classical initial stability metric in naval architecture:

- `BM = I_T / ∇`
- `KM = KB + BM`
- `GM = KM - KG`

Classical interpretation:

- `GM > 0` → statically stable
- `GM ≈ 0` → marginal stability
- `GM < 0` → unstable

This interpretation is **instantaneous**.
It evaluates stability at a point in time and does not encode memory, accumulation, or operational trust.

6.2 Structural Interpretation in SSB

SSB treats `GM` not as a guarantee, but as a **structural margin**.

Including free-surface effects, SSB uses an effective margin:

```
GM_eff = (KB + I_T/∇) - KG - FSC
```

Where:

- `FSC` represents free-surface correction and related destabilizing allowances

Important:
SSB does **not** replace `GM` or `GM_eff`.
It treats them as **inputs** to a higher-level structural governance decision.

In SSB:

- positive `GM_eff` is **necessary**
- positive `GM_eff` is **not sufficient**

6.3 Structural Admissibility Condition (Core Governor)

SSB evaluates structural admissibility using normalized margin and accumulation logic.

Define normalized margin:

```
margin = GM_eff / GM_safe
```

Where:

- `GM_safe` is a **declared operational minimum**, not a tuned or learned parameter

Define structural observables:

- `a = clamp01(margin)` (alignment / permission ratio)
- `r = max(0, 1 - margin)` (instantaneous risk)
- `s := s + max(0, r - r_safe)` (accumulated structural resistance)

Governance rules:

- **ABSTAIN** if required inputs are invalid or undefined
- **DENY** if:
  - `GM_eff <= 0` (classical instability), or
  - `a < a_min`, or
  - `s >= s_max`
- **otherwise ALLOW**

This mechanism is a **deterministic safety governor**:

- no simulation
- no machine learning
- no heuristics
- no tuning across runs

6.4 Declared Thresholds and Structural Conservatism

SSB operates exclusively on **declared thresholds**.
These thresholds are **not tuned**, **not optimized**, and **not adjusted during execution**.

Their role is not to predict failure, but to **bound operational trust** in a conservative, auditable manner.

SSB deliberately separates two questions:

- *Is the physics still correct?*
- *Is it still structurally responsible to rely on that correctness?*

The following parameters define that responsibility boundary.

Declared Effective Stability Floor — `GM_safe`

`GM_safe` represents the **minimum effective stability margin below which continued operational reliance is no longer ethically admissible**, even if classical stability remains positive.

Important clarifications:

- `GM_safe` is **not a prediction threshold**
- `GM_safe` is **not a failure boundary**
- `GM_safe` is **not tuned to outcomes**

It is a **declared trust floor**.

SSB treats classical stability margins as *inputs*, not guarantees.
Positive `GM_eff` is **necessary**, but **not sufficient**, for trust.

Normalized Alignment Requirement — `a_min`

SSB evaluates alignment using the normalized margin:

```
margin = GM_eff / GM_safe
a = clamp01(margin)
```

The parameter `a_min` defines the **minimum retained fraction of declared safe margin** required to justify continued reliance.

Structural interpretation:

- `a >= a_min`
  → alignment remains structurally defensible

- `a < a_min`
  → reliance becomes structurally unjustified, regardless of physical validity

This rule encodes a conservative principle:

Trust is denied when safety margins degrade beyond an explicitly declared fraction — not when physics fails.

Resistance Tolerance — `r_safe`

SSB introduces instantaneous structural risk as:

```
r = max(0, 1 - margin)
```

The parameter `r_safe` defines a **tolerance band** below which minor or transient degradation is **not accumulated**.

This prevents:

- noise penalization
- spurious denial
- overreaction to isolated excursions

Only **sustained or repeated erosion beyond `r_safe`** contributes to lifecycle resistance.

Structural Resistance Budget — `s_max`

SSB treats operational trust as a **finite, exhaustible resource**.

Structural resistance evolves as:

```
s(t+1) = s(t) + max(0, r(t) - r_safe)
```

The parameter `s_max` defines the **maximum allowable accumulated resistance**.

Once exceeded:

- trust is considered structurally exhausted
- denial is **irreversible within the lifecycle**
- no spontaneous recovery is permitted

This enforces a core SSB invariant:

Correctness does not restore trust. Only structural reset may do so.

Threshold Discipline and Governance Integrity

All thresholds in SSB are:

- declared **before execution**
- immutable **during execution**
- auditable **after execution**

SSB **does not search for thresholds**.
SSB **does not adapt thresholds**.
SSB **does not infer thresholds from data**.

Thresholds define **responsibility limits**, not model performance.

This discipline ensures that SSB remains:

- conservative by design
- deterministic by construction
- defensible under audit
- immune to optimization pressure

6.4.1 Threshold Declaration Guide (Non-Binding, Non-Prescriptive)

This section explains how **thresholds in Shunyaya Structural Buoyancy (SSB)** are to be **declared, interpreted, and governed**.

This guide is **informational only**.
It does **not** prescribe numeric values.
It does **not** introduce tuning, optimization, or performance targeting.

Thresholds in SSB express **operational responsibility boundaries**, not physical failure limits.

A. Purpose of Thresholds in SSB

SSB thresholds do **not** predict failure.
They do **not** estimate risk probabilities.
They do **not** encode safety margins as performance targets.

Their sole purpose is to define **when continued reliance on buoyancy and stability becomes structurally unjustifiable**, even while physics remains correct.

Thresholds answer the governance question:

"Up to what point is it responsible to continue relying on this floating state?"

B. Declared Effective Stability Floor — `GM_safe`

`GM_safe` represents a **declared trust floor** for effective stability.

It is:

- **not** a prediction threshold
- **not** a failure boundary
- **not** a tuned parameter
- **not** a certification replacement

Structural meaning:

- `GM_eff > GM_safe`
  → effective stability remains within declared trust limits
- `GM_eff <= GM_safe`
  → continued reliance becomes structurally unjustified, even if `GM_eff > 0`

`GM_safe` defines **when trust should be withdrawn**, not when instability occurs.

C. Normalized Alignment Requirement — `a_min`

SSB evaluates alignment using the normalized margin:

```
margin = GM_eff / GM_safe
a = clamp01(margin)
```

`a_min` defines the **minimum retained fraction** of the declared trust floor required to justify continued reliance.

Structural interpretation:

- `a >= a_min`
  → alignment remains structurally defensible
- `a < a_min`
  → trust is denied, regardless of classical stability

This rule encodes a conservative principle:

Trust is withdrawn when declared safety margins degrade beyond an explicitly stated fraction — not when physics fails.

D. Instantaneous Risk Tolerance — `r_safe`

SSB defines instantaneous structural risk as:

```
r = max(0, 1 - margin)
```

`r_safe` defines a **tolerance band** below which minor or transient degradation does **not** accumulate resistance.

Purpose of `r_safe`:

- prevent noise penalization
- avoid spurious denial
- block overreaction to isolated excursions

Only **sustained or repeated erosion** beyond `r_safe` contributes to lifecycle resistance.

E. Structural Resistance Budget — `s_max`

SSB treats operational trust as a **finite, exhaustible resource**.

Structural resistance evolves as:

```
s(t+1) = s(t) + max(0, r(t) - r_safe)
```

`s_max` defines the **maximum allowable accumulated resistance**.

Once `s(t) > s_max`:

- trust is considered **structurally exhausted**
- denial is **irreversible within the lifecycle**
- no spontaneous recovery is permitted

This enforces a core SSB principle:

Correctness does not restore trust. Only explicit structural reset may do so.

F. Threshold Discipline and Governance Integrity

All thresholds in SSB must be:

- **declared before execution**
- **immutable during execution**
- **auditable after execution**

SSB must not:

- search for thresholds
- optimize thresholds
- infer thresholds from data
- adapt thresholds during runtime

Thresholds define **responsibility limits**, not model performance.

This discipline ensures SSB remains:

- conservative by design
- deterministic by construction
- defensible under audit
- immune to optimization pressure

G. Organizational Interpretation (Clarification)

Different organizations may declare different thresholds due to:

- asset class differences
- operational context
- regulatory posture
- risk tolerance philosophy

SSB does **not** judge the values chosen.

SSB enforces only this rule:

Once declared, thresholds are obeyed without exception.

H. What This Guide Does Not Do

This guide does **not**:

- recommend numeric values
- suggest “safe” defaults
- imply certification compliance
- weaken DENY semantics
- introduce probabilistic interpretation

Its purpose is clarity, not calibration.

6.5 Formal Properties and Governance Guarantees

Shunyaya Structural Buoyancy (SSB) is not only deterministic by construction — it satisfies a set of **formal governance guarantees** that can be stated and verified independently of domain interpretation.

These properties follow directly from the SSB update equations and denial rules. No additional assumptions are required.

Proposition 1 — Conservative Ordering of Denial

Under any monotonic or non-increasing effective stability process, SSB denial **always precedes or coincides with classical instability**.

Formally:

Let effective stability evolve as:

```
GM_eff(t) = GM(t) - FSC(t) - delta(t)
```

with `GM_eff(t)` non-increasing in `t`.

Then SSB denial occurs at time `t*` such that:

`GM_eff(t*) > 0`
or
`GM_eff(t*) = 0`

but **never** at any `t` where:

`GM_eff(t) < 0` and SSB previously allowed reliance.

Interpretation

SSB cannot permit operation beyond physical instability.
It introduces a **governance buffer**, not a risk extension.

Proposition 2 — Irreversibility of Trust Denial

Once structural resistance exceeds its declared maximum, trust denial is irreversible within the lifecycle.

Structural resistance evolves as:

```
s(t+1) = s(t) + max(0, r(t) - r_safe)
```

with initial condition:

```
s(0) >= 0
```

If at some time `t*`:

```
s(t*) > s_max
```

then for all subsequent times `t > t*`:

```
SSB_status(t) = DENY
```

unless an **explicit structural reset** is performed.

Interpretation

SSB forbids spontaneous recovery of trust.
Correctness at later times does not restore permission.

This property enforces lifecycle honesty and prevents deferred-risk normalization.

Proposition 3 — Deterministic Idempotence

For any fixed sequence of declared inputs and thresholds, SSB produces identical governance outcomes under re-evaluation.

Formally:

Given identical sequences:

```
{GM_eff(t)}, {GM_safe}, {a_min}, {r_safe}, {s_max}
```

then:

```
SSB({inputs}) = constant
```

across:

- re-runs
- machines
- environments
- execution time

Interpretation

SSB contains:

- no hidden state

- no stochasticity
- no learning
- no adaptive behavior

Governance outcomes are **fully reproducible and audit-stable**.

Proposition 4 — Non-Increasing Permissiveness

Within a lifecycle, SSB permissiveness may degrade but never improve.

Let permissiveness ordering be defined as:

```
ALLOW > RESTRICTED > DENY
```

Then SSB enforces:

```
status(t+1) <= status(t)
```

for all `t`, unless a formal reset occurs.

Interpretation

SSB encodes structural memory.
It prevents oscillation, gaming, or reliance cycling.

Consequence — Governance Completeness

Together, these properties guarantee that SSB is:

- conservative relative to physics
- monotone in trust degradation
- irreversible in denial
- deterministic under replay
- closed under lifecycle evaluation

SSB therefore qualifies as a **formal governance layer**, not an analytical heuristic.

---

7. Structural Buoyancy Principle

SSB may be summarized as:
Floating is not a force equilibrium.
Floating is structurally admissible only while restoring alignment exceeds accumulated drift.

This principle **complements Archimedes** without modifying him.

Archimedes answers *whether* a body floats.
SSB answers *whether floating may be trusted*.

---

8. Phase I — Formalization of Structural Buoyancy

Phase I establishes the formal, deterministic foundation of Shunyaya Structural Buoyancy.
This phase defines what SSB is and how it governs trust, without relying on empirical validation.

Phase I includes:

- Structural reframing of buoyancy as a governed state
- Definition of structural posture `(m, a, s)`
- Governance rules (ALLOW / DENY / ABSTAIN)
- Formal mapping to classical stability (`GM`, `GM_eff`)
- Deterministic admissibility logic using declared thresholds
- Absence of simulation, prediction, or tuning

Outcome of Phase I:
A complete, closed, deterministic governance framework for buoyancy — ready for validation.

(No empirical results are required at Phase I.)

Structural Resistance Exhaustion Rule (Authoritative)

Shunyaya Structural Buoyancy (SSB) defines exhaustion of structural trust as occurring **at or beyond** the declared resistance limit.

Formally:
DENY if `s >= s_max`

This interpretation is intentional and conservative. The declared resistance budget is treated as a **closed boundary**, not an open one. Once the accumulated structural resistance reaches the declared maximum, continued reliance is no longer structurally admissible.

This rule applies uniformly across all phases, scripts, and interpretations of SSB.

Declared Thresholds as Governance Contracts

Shunyaya Structural Buoyancy (SSB) operates exclusively on **declared thresholds**. These thresholds are not derived from empirical failure data, not optimized through simulation, and not inferred from operational outcomes.

This is intentional.

In SSB, a threshold does **not** answer the question:

"At what value will failure occur?"

Instead, a threshold answers the governance question:

"Up to what point is it structurally responsible to continue relying on this floating state?"

Accordingly:

• `GM_safe` defines a **trust reference level**, not a failure boundary
• `a_min` defines a **minimum retained fraction of declared trust**, not stability loss
• `r_safe` defines a **tolerance band** for ignoring minor or transient erosion
• `s_max` defines a **finite resistance budget**, beyond which trust is exhausted

These parameters together form a **governance contract**, not a predictive model.

SSB evaluates the consequences of **explicitly declared responsibility limits**.
It does not attempt to discover, tune, or optimize those limits.

Formally, SSB enforces:

• thresholds are declared **before execution**
• thresholds remain **immutable during execution**
• thresholds are **auditable after execution**
• no internal adjustment, fitting, or learning is permitted

Different declared thresholds may lead to **earlier or later denial of reliance**.
This variability reflects **organizational risk posture**, not algorithmic uncertainty.

The deterministic guarantee of SSB remains unchanged:

For fixed inputs and fixed declared thresholds, SSB produces **one and only one reproducible governance outcome**.

This separation is foundational:

• Classical physics determines **correctness**
• SSB governs **permission to rely on correctness**

SSB therefore does not compete with stability standards or regulatory limits.
It formalizes a missing layer above them: **the ethics and responsibility of continued reliance**.

Illustrative Threshold Context (Non-Binding)

The thresholds used in Shunyaya Structural Buoyancy (SSB) are **declared governance parameters**, not empirically derived safety limits.
They are intentionally conservative and exist to define **responsibility boundaries**, not failure points.

To aid interpretation only, the table below provides **illustrative contextual mapping** against commonly understood engineering notions.
This mapping is **non-normative** and **non-binding**.

SSB Parameter	Illustrative Engineering Context	Structural Interpretation
`GM_safe`	Order-of-magnitude near conservative minimum effective stability margins used in practice	Declared trust reference level, not instability boundary
`a_min`	~70% retained margin	Minimum acceptable alignment between current margin and declared trust floor
`r_safe`	Small tolerance band for ignoring minor transient erosion	Structural noise immunity, not risk modeling
`s_max`	Finite lifecycle exposure budget	Explicit exhaustion of justified trust
`s_warn_frac`	Early warning fraction of resistance budget	Monitoring trigger, not denial condition

Mandatory clarifications:

• These mappings **do not justify** threshold values
• These mappings **do not assert regulatory compliance**
• These mappings **do not prescribe recommended parameters**
• These mappings **must not be interpreted as failure predictors**

SSB remains agnostic to the “correct” numerical values of thresholds.
Its contribution is the **formal governance consequence** of whatever values are explicitly declared.

---

9. Phase II Canonical Validation of Shunyaya Structural Buoyancy (SSB)

Phase-II validation establishes **Shunyaya Structural Buoyancy (SSB)** as a deterministic, lifecycle-governed safety subsystem.
All tests in this phase were executed under the following guarantees:

- **No simulations**
- **No probabilistic assumptions**
- **No stochastic inputs**
- **No tuning between runs**
- **Deterministic execution and closure**

Phase-II focuses on validating whether **positive classical stability (GM > 0)** is sufficient for **structural trust**, and whether SSB introduces a **governance buffer** that denies reliance *before* physical failure.

9.1 Validation Scope and Governance Invariance

Across all Phase-II tests:

• **Classical hydrostatics remained unchanged**
• **All SSB governance rules were held constant**
• **All thresholds were declared and immutable within each run**
• **Decisions were monotonic, deterministic, and reproducible**

SSB operated strictly **above** classical physics, governing **permission to rely**, not force.

Phase II validates governance behavior under fixed rules. It does not introduce tuning, optimization, or probabilistic interpretation.

9.2 Displacement Sweep Validation (∇-Sweep) — Structural Margin vs Trust

Objective
To determine whether classical positive stability alone guarantees structural trust under increasing displacement.

Method Summary

- Displaced volume ∇ was swept while holding geometry fixed
- Classical relations used unchanged:
    - `BM = I_T / ∇`
    - `KM = KB + BM`
    - `GM = KM - KG`
    - `GM_eff = GM - FSC`

- SSB governance evaluated trust using:
    - `margin = GM_eff / GM_safe`
    - `a = clamp01(margin)`
    - `r = max(0, 1 - margin)`
    - `s(t+1) = s(t) + max(0, r - r_safe)`

Canonical Findings

- In both baseline and stressed configurations:
    - **SSB denial always occurred while GM was still positive**
    - Classical instability occurred significantly later
- Under degraded conditions (raised KG and FSC):
    - The denial boundary shifted earlier
    - The safety buffer widened deterministically

Key Result

Positive GM is necessary but not sufficient for operational trust.

SSB introduces a **deterministic buffer** between physical stability and permissible operation.

9.3 Free-Surface Accumulation Validation (Multi-Tank FSC Ladder)

Objective
To validate that SSB responds deterministically to stepwise accumulation of free-surface effects, even when classical stability remains positive.

Method Summary

- Free-surface corrections were accumulated as:
    - `FSC_total = sum(FSC_i)`
- Effective stability evaluated as:
    - `GM_eff = GM - FSC_total`
- Governance rules unchanged

Canonical Findings

- In all ladder configurations:
    - **SSB denial occurred immediately when alignment ratio `a` fell below `a_min`**
    - Denial occurred **before any classical instability**
- FSC accumulation compressed the admissible envelope monotonically

Key Result

Buoyancy does not fail suddenly; trust erodes deterministically.

SSB correctly governs trust under structural degradation without prediction or tuning.

9.4 Cyclic Fatigue Validation — Structural Time and Resistance Accumulation

Objective
To validate that SSB governs trust **over time**, not just at a static point, using deterministic lifecycle accumulation.

Method Summary

- Stability degraded via a deterministic square-wave disturbance:
  - `GM_eff(t) = GM - FSC - delta(t)`
- Structural resistance accumulated as:
  - `s(t+1) = s(t) + max(0, r(t) - r_safe)`
- Governance rules unchanged

Canonical Findings

- Two regimes were demonstrated:
  1. **Immediate hard denial** when worst-case disturbance consumed stability
  2. **Delayed denial via accumulated fatigue**, even with positive GM
- Denial occurred **without any violation of classical stability**

Key Result

SSB governs lifecycle trust, not instantaneous equilibrium.

Floating may remain physically valid while becoming structurally unsafe to rely upon.

9.5 Phase-II Synthesis

Across displacement, accumulation, and time:

1. **SSB denial always precedes classical instability**
2. Trust erosion is **monotonic, deterministic, and reproducible**
3. No simulations or heuristics are required
4. Governance behavior is invariant across test classes
5. Structural time (`s(t)`) is a first-class safety signal

9.6 Phase-II Formal Conclusion

Phase-II validation confirms that:

Buoyancy is not a binary fact.
It is a structurally governed permission.

SSB introduces a **deterministic governance envelope** that denies trust before physical failure — without modifying classical hydrostatics.

This establishes SSB as:

- **A trust governor, not a predictor**
- **A safety overlay, not a force model**
- **A lifecycle-complete Phase-II Shunyaya subsystem**

Combined Exposure Governance Pattern (Conceptual Validation)

Phase II validation families are intentionally constructed as **independent deterministic tests**. However, real-world trust erosion rarely occurs through a single isolated mechanism.

Shunyaya Structural Buoyancy (SSB) addresses this reality not by coupling simulations, but by enforcing **governance invariance under composition**.

The combined exposure governance pattern is defined as follows:

• multiple degradation modes may coexist
• each mode is evaluated deterministically
• no coupling or tuning is introduced
• structural resistance accumulates monotonically

Typical combined exposure conditions include:

• gradual displacement increase
• cumulative free-surface effects
• repeated cyclic disturbance
• slow drift of stability margins

Under SSB governance:

• each degradation contributes independently to erosion of alignment `a` or growth of resistance `s`
• denial may occur even when no single degradation is extreme
• denial always precedes classical instability
• governance behavior remains deterministic and replay-invariant

This pattern demonstrates a critical distinction:

Classical analysis explains **how failure occurs**.
SSB explains **how trust is exhausted before failure**.

No new equations are required.
No predictive coupling is introduced.

SSB denial emerges purely from **structural accumulation**, not event severity.

9.7 Canonical Example Run — End-to-End Phase II + Phase III Evaluation

This section provides a **canonical, end-to-end execution sequence** for Shunyaya Structural Buoyancy (SSB).

It exists solely to improve **reproducibility, reviewability, and onboarding clarity**.

It does **not** introduce:

- new logic
- new thresholds
- new equations
- new interpretations

All runs remain **deterministic**, **offline**, and **audit-ready**.

Purpose of This Canonical Run

SSB validation intentionally uses **multiple independent deterministic scripts**, because trust governance must be invariant across:

- static margin erosion
- accumulated free-surface effects
- lifecycle fatigue
- operational posture classification

This canonical sequence allows a reviewer to:

- reproduce all Phase II behaviors
- observe invariant denial ordering
- confirm Phase III envelope classification
- do so without modifying any code

Canonical Execution Order

The following sequence represents a **complete, minimal SSB evaluation cycle**.

Step 1 — Displacement Sweep (Static Margin Erosion)

Objective:
Validate that SSB denies trust **before** classical instability under increasing displacement.

Key invariant demonstrated:

- `GM_eff > 0` may still result in **DENY**

Output:

- deterministic denial boundary
- reproducible margin degradation

Step 2 — Free-Surface Accumulation (Multi-Tank FSC Ladder)

Objective:
Validate deterministic trust erosion under **stepwise accumulation** of destabilizing effects.

Key invariant demonstrated:

- trust erodes monotonically under accumulation
- denial occurs without simulation or prediction

Output:

- immediate denial when `a < a_min`
- compressed admissible envelope

Step 3 — Cyclic Fatigue (Structural Time and Resistance Accumulation)

Objective:
Validate lifecycle governance using deterministic disturbance over time.

Key invariant demonstrated:

- `s(t)` accumulates monotonically
- denial may occur while `GM_eff > 0`
- no spontaneous trust recovery

Structural update rule applied:

- `s(t+1) = s(t) + max(0, r(t) - r_safe)`

Output:

- delayed denial under repeated exposure
- identical results under replay

Step 4 — Phase III Operational Envelope Classification

Objective:
Classify Phase II outcomes into **operational postures** without altering decisions.

Important clarification:

- Phase III does **not** change DENY logic
- Phase III does **not** weaken governance
- Phase III adds **interpretive context only**

Possible envelopes:

- **ALLOW_NORMAL**
- **ALLOW_RESTRICTED_MONITOR**
- **DENY_FINAL**
- **ABSTAIN_HUMAN_REVIEW**

What This Canonical Run Proves

Across all four steps, the following properties are verified simultaneously:

- classical hydrostatics remain unchanged
- SSB denial always precedes classical instability
- trust erosion is deterministic and monotonic
- denial is irreversible within a lifecycle
- results are identical across machines and re-runs

This establishes SSB as a **closed, audit-grade trust governance system**.

What This Canonical Run Does NOT Do

This sequence does **not**:

- predict failure
- estimate timelines
- assign probabilities
- optimize safety margins
- tune thresholds

It exists to demonstrate **governance invariance**, not performance.

Why This Matters

For reviewers, auditors, and regulators, this section provides:

- a single reproducible path through SSB
- zero ambiguity about execution order
- confidence that SSB is not "one script"
- proof that governance behavior is invariant

SSB remains conservative by design.

9.8 Retrospective Validation Narrative (Non-Predictive, Governance-Only)

This section provides **retrospective structural interpretation** of Shunyaya Structural Buoyancy (SSB) decisions.

It is **not** a prediction exercise.
It is **not** a failure model.
It does **not** infer timelines, probabilities, or causal certainty.

Its sole purpose is to make explicit **what SSB governs**:

the point at which continued reliance on buoyancy becomes structurally unjustifiable — even while floating persists.

A. Retrodiction Without Hindsight Tuning

SSB may be applied retrospectively to known operational histories under the following strict conditions:

- all inputs are declared from documented information
- all thresholds are declared ex ante
- no parameters are fitted to outcomes
- no timelines are optimized to match failure events
- the evaluation is performed once, under frozen rules

SSB does **not** ask:

- "When would failure occur?"
- "Could this have been predicted?"

SSB asks a different and prior question:

"At what point should trust have been withdrawn?"

This distinction is mandatory.

B. Illustrative Retrospective Pattern I — Persistent Stability, Eroded Trust

Consider a floating system that:

- remains physically afloat
- retains positive effective stability (`GM_eff > 0`)
- passes classical checks repeatedly over time

Operational history shows:

- repeated disturbance
- cumulative free-surface exposure
- gradual erosion of effective margins

Under SSB governance:

- `margin = GM_eff / GM_safe` degrades monotonically
- normalized alignment `a = clamp01(margin)` eventually falls below `a_min`
- or accumulated resistance `s(t)` exceeds `s_max`

At that point:

- SSB outputs **DENY**
- classical buoyancy and stability remain valid
- no failure is predicted

Interpretation
The system may continue to float.
What is withdrawn is **permission to rely** on that floating state.

This intermediate condition — *physically stable yet structurally denied* — does not exist in classical buoyancy theory.

C. Illustrative Retrospective Pattern II — Delayed Failure After Long Apparent Safety

Many real-world incidents share a common structure:

- long periods of apparent stability
- no single triggering violation
- failure occurring after accumulated exposure

Classical analysis explains **how** failure occurred.

SSB explains **when reliance should have stopped**.

Under SSB evaluation:

- denial occurs **before** classical instability
- denial does **not** claim inevitability of failure
- denial marks the exhaustion of justified trust

Interpretation
SSB reframes delayed failure not as a surprise, but as a **governance overextension**.

Physics remains correct.
Reliance becomes irresponsible.

D. Trust Denial Is Not Failure Prediction

A critical boundary must be preserved:

- **Failure prediction** concerns future physical outcomes
- **Trust denial** concerns present operational responsibility

SSB performs the latter.

A DENY outcome means:

- "Do not continue relying on this floating state"

It does **not** mean:

- "This system will fail"
- "Failure timing is known"
- "Collapse is inevitable"

This separation preserves scientific rigor while strengthening safety accountability.

E. Ethical Boundary (Mandatory Interpretation Rule)

SSB retrospective analysis must **never** be used to:

- assert inevitability of failure
- assign blame
- replace forensic investigation
- justify extended operation after denial
- reinterpret denial as acceptable risk

SSB provides **structural refusal timing**, not outcome certainty.

Trust denial is an **ethical boundary**, not a forecast.

F. Why This Narrative Matters

This narrative makes explicit what Phase II already proves:

- classical buoyancy answers correctness
- SSB governs responsibility

SSB introduces a missing language in safety-critical domains:

the language of trust exhaustion before failure.

G. Canonical Retrospective Governance Replay (Abstracted)

This subsection demonstrates how Shunyaya Structural Buoyancy (SSB) may be applied retrospectively to a **documented operational history**, without referencing any specific incident, asset, operator, or outcome.

The purpose is **illustrative**, not evidentiary.

Abstracted Scenario Description

Consider a floating asset with the following documented properties over time:

• positive effective stability (`GM_eff > 0`) at all recorded checkpoints
• repeated operational exposure events
• gradual increase in free-surface effects and load variability
• no single excursion exceeding regulatory limits
• continued operation under apparent classical compliance

No failure is assumed.
No outcome is asserted.

Declared Retrospective Inputs (Frozen)

For the retrospective replay:

• all inputs are taken from documented historical records
• all thresholds are declared **once**, prior to evaluation

• no values are tuned to align with any outcome
• no time-to-failure assumptions are made

The replay is executed exactly once.

Governance Replay Result

Under SSB evaluation:

• classical buoyancy and stability remain valid throughout
• alignment ratio `a(t)` degrades monotonically
• accumulated resistance `s(t)` increases under repeated exposure
• a deterministic point is reached where `s >= s_max` or `a < a_min`

At that point:

→ SSB issues DENY

This denial occurs **while physical stability remains positive**
and **before any known failure event** (if one exists).

Interpretation Boundary (Mandatory)

This denial means:

• continued reliance is no longer structurally justifiable

It does **not** mean:

• failure was inevitable
• failure timing was knowable
• operators were negligent
• different decisions would guarantee safety

The governance signal concerns **responsibility**, not outcome.

Why This Is Real-World Applicable

Any real-world incident that exhibits:

• delayed failure
• cumulative degradation
• prolonged operation under apparent compliance

can be structurally replayed using this template **without naming the incident**.

This preserves:

• ethical neutrality
• legal safety
• methodological rigor
• cross-domain applicability

SSB does not explain *what failed*.
It explains *when trust should have stopped*.

---

10. Phase III — Operationalization and Structural Expansion of Shunyaya Structural Buoyancy

Phase III transitions Shunyaya Structural Buoyancy (SSB) from a validated structural framework into an operationally interpretable, certifiable, and ethically constrained framework.

While Phase I established formal correctness and Phase II established deterministic behavioral validity, Phase III addresses a different question:

How should SSB be used in real systems without altering physics, predicting failure, or increasing risk?

Phase III does not introduce new equations or tuning.
It introduces **structural interpretation, operational envelopes, and governance boundaries**.

10.1 From Binary Decisions to Operational Envelopes

Phase II establishes a strict governance output:

- ALLOW
- DENY
- ABSTAIN

Phase III refines how **ALLOW** is interpreted operationally.

Instead of treating ALLOW as an unlimited green signal, SSB introduces **permission envelopes**:

Let the structural state be:
```
E(t) = {GM_eff(t), a(t), r(t), s(t)}
```

Operational interpretation:

- **ALLOW (Normal Operation)**
  `a >= a_min` and `s << s_max`
- **ALLOW (Restricted / Monitor)**
  `a >= a_min` and `s approaching s_max`
- **DENY (Cease Reliance)**
  `a < a_min` or `s >= s_max`

This refinement:

- does not alter the decision logic
- does not weaken denial
- does not introduce prediction

It allows safe actions such as:

- speed limits
- cargo restrictions
- time-bounded operation
- increased inspection cadence

SSB thus becomes **actionable without becoming permissive**.

10.2 Certification and Compliance Mapping

SSB is designed to **augment**, not replace, existing engineering and regulatory standards.

Classical certification frameworks typically verify:

- static stability
- momentary margins
- post-event compliance

SSB introduces a missing layer:
lifecycle trust governance.

Mapping is direct and transparent:

- Classical requirement: `GM > 0`
  SSB augmentation: `GM_eff >= GM_safe` over time
- Classical safety factor: fixed
  SSB augmentation: `s(t)` accumulation
- Classical fatigue handling: post-hoc
  SSB augmentation: deterministic denial before reliance becomes unsafe

Because:

- thresholds are declared
- rules are monotonic
- no tuning is allowed

SSB aligns naturally with certification logic rather than conflicting with it.

SSB is therefore best interpreted as a **structural compliance amplifier**, not a competing standard.

10.3 Retrodictive Safety Interpretation (Non-Predictive)

Phase III introduces a critical interpretive capability: **retrodictive governance analysis**.

SSB is not used to ask:
"Could we have predicted failure?"

Instead, it asks:
"At what point should trust have been denied?"

Using published parameters and declared thresholds:

- no tuning
- no fitting
- no hindsight adjustment

SSB identifies the **first denial point** where continued reliance became structurally unsafe.

This reframes many failures not as physics breakdowns, but as **trust overextension**.

Importantly:

- SSB does not claim failure timing
- SSB claims refusal timing

This distinction preserves scientific rigor while improving safety accountability.

10.3.1 Retrodictive Governance Lens (Clarification)

Shunyaya Structural Buoyancy (SSB) must be interpreted through a **retrodictive governance lens**, not a predictive one.

SSB does **not** ask:

- “When would failure occur?”
- “Could this event have been predicted?”
- “What probability should be assigned to collapse?”

SSB asks a different and prior question:

“At what point should operational trust have been withdrawn?”

Trust Denial Is Not Failure Prediction

A critical distinction:

- **Failure prediction** concerns future physical outcomes
- **Trust denial** concerns present operational responsibility

SSB does not claim that a system *will* fail after denial.
It claims that **continued reliance becomes structurally unjustifiable**.

A system may:

- remain physically afloat
- retain positive stability
- continue operating in reality

and yet:

- no longer deserve trust as a governed state

This distinction preserves scientific rigor while strengthening safety accountability.

Retrodiction Without Hindsight Tuning

When applied to historical events, SSB is used strictly in the following manner:

- inputs are declared **from documented, public information**
- thresholds are declared **ex ante**
- no parameters are fitted to outcomes
- no timelines are optimized to match failure moments

SSB is evaluated once.

The output is interpreted as:

“This is the earliest point at which trust exhaustion becomes structurally evident.”

This is **not hindsight fitting**.
It is **governance interpretation under frozen rules**.

Why Retrodiction Matters

Many catastrophic events do not represent sudden physical breakdowns.
They represent **prolonged operation beyond responsible trust limits**.

Classical analysis explains *how* failure occurred.
SSB explains *when trust should have stopped*.

This reframing:

- preserves respect for physics
- avoids speculative prediction
- introduces accountability without blame
- exposes governance blind spots without hindsight bias

Ethical Boundary (Mandatory)

SSB retrodictive analysis must never be used to:

- assert inevitability of failure
- claim causal certainty
- replace forensic investigation
- justify extended operation after denial

SSB provides **structural refusal timing**, not outcome certainty.

Trust denial is an ethical boundary, not a forecast.

10.4 Cross-Domain Structural Transfer

Although motivated by buoyant systems, SSB is not domain-bound.

The governing pattern applies wherever:

- equilibrium exists
- degradation accumulates
- collapse is delayed
- trust is currently binary

The transferable structure is:
`(m, a, s)` with deterministic governance.

Examples of structural transfer (without re-derivation):

- floating infrastructure and platforms
- fluid reservoirs and containment
- biological buoyancy and cavities
- economic and financial “floating equilibria”
- energy systems with metastable balance

In each case, SSB governs **permission**, not outcome.

10.5 SSB as a Canonical Lifecycle Trust Governor

Shunyaya Structural Buoyancy (SSB) is presented as a buoyancy-focused system only by choice of demonstration domain.

Its governing structure is **not buoyancy-specific**.

SSB formalizes a general lifecycle pattern:

- a correct equilibrium exists
- degradation accumulates without immediate failure
- continued reliance becomes unsafe before collapse
- classical analysis remains correct but silent on trust

This pattern is expressed structurally as:

```
(m, a, s)
```

where:

- `m` remains an invariant physical or mathematical output
- `a` represents normalized alignment between safety margin and declared trust floor
- `s` represents accumulated resistance from lifecycle exposure

The collapse invariant holds:

```
phi((m, a, s)) = m
```

Physical correctness is preserved.
Operational trust is governed.

Canonical Scope of Applicability

SSB applies to any system that satisfies **all** of the following conditions:

1. A stable equilibrium or conserved output exists
2. Degradation may accumulate without violating governing laws
3. Failure is delayed rather than instantaneous
4. Operational reliance is binary or weakly governed
5. Trust exhaustion is currently unformalized

SSB does **not** require:

- new physics
- probabilistic modeling
- predictive simulation
- control intervention

Only structural governance.

Demonstration vs Generalization

Buoyancy is the **demonstration case**, not the limiting case.

SSB does not claim to replace domain-specific theory.
It overlays a **trust-governance layer** above correct theory.

Other domains may instantiate the same `(m, a, s)` structure **without reinterpretation**, provided:

- the collapse invariant is preserved
- denial remains irreversible
- thresholds are declared, not tuned

Conservatism of Scope

This generalization is:

- conceptual, not empirical
- structural, not predictive
- permissive of future instantiation, not prescriptive

SSB makes no claim that all equilibria *should* be governed in this way.

It establishes that equilibria *can* be governed responsibly when trust exhaustion matters.

10.6 Ethical and Safety Lock-In

Phase III formally constrains how SSB may be used.

SSB must **never** be used to:

- justify extended operation under DENY
- relax declared thresholds during runtime
- override human judgment under ABSTAIN
- convert denial into risk acceptance

Ethical invariants:

- DENY is final
- ABSTAIN blocks automation
- thresholds must be declared before operation
- no runtime tuning is permitted

These constraints ensure that SSB remains:
conservative by design, not aggressive by optimization.

10.7 Phase III Synthesis

Phase III establishes that:

1. SSB decisions can be operationalized without weakening safety
2. Governance integrates cleanly with certification logic
3. Trust denial can be identified earlier without prediction
4. Structural transfer is possible without new mathematics
5. Ethical misuse is structurally prevented

SSB is no longer only a validated framework.
It becomes an imple**mentable trust-governance standard**.

10.x Canonical Execution Entry (Deterministic Aggregation)

Phase III introduces multiple canonical validation families, each demonstrating a distinct structural behavior of SSB under controlled conditions. These families are intentionally independent in order to preserve clarity of interpretation.

For operational reproducibility, SSB defines a canonical execution entry that aggregates these families without altering their internal logic.

The purpose of this entry is reproducibility and auditability, not optimization or coupling.

A) Objective

The canonical execution entry allows a complete SSB validation sequence to be executed deterministically using a single invocation, while preserving:

- identical thresholds,
- identical disturbance schedules,
- identical deterministic inputs,
- identical replay behavior.

No cross-family interaction or parameter adjustment is permitted.

B) Canonical validation families

The canonical execution entry sequentially executes:

1. Displacement sweep validation
   Demonstrates envelope contraction as displacement increases.
2. Multi–free-surface ladder validation
   Demonstrates ordered degradation under increasing free-surface effects.
3. Cyclic disturbance accumulation validation
   Demonstrates monotonic growth of structural resistance `s(t)`.
4. Phase III operational envelope classification
   Demonstrates governance state transitions across lifecycle exposure.

Each family remains independently valid and executable.

C) Aggregated reporting

The canonical execution entry produces a deterministic summary containing:

- first occurrence of ALLOW_RESTRICTED_MONITOR,
- first occurrence of DENY_FINAL,
- classical instability point (if present),
- envelope transition ordering.

This summary is descriptive only and must not be interpreted as optimization or performance scoring.

D) Structural constraints

The canonical execution entry must satisfy the following invariants:

- no new equations introduced,
- no parameter tuning,
- no adaptive behavior,
- no cross-run learning,
- no modification of individual validation outputs.

The execution entry acts only as an orchestrator.

E) Purpose in engineering practice

The canonical execution entry serves three purposes:

1. Enables rapid independent verification by reviewers.
2. Guarantees that SSB behavior is reproducible across implementations.
3. Provides a consistent reference baseline for future SGS extensions.

The aggregation layer exists solely for execution convenience; structural meaning remains within the individual validation families.

---

11. Phase IV — Structural Governance Systems (SGS)

A New Scientific Class Above Physical Law

11.1 Purpose of Phase IV

Phases I–III establish Shunyaya Structural Buoyancy (SSB) as a deterministic, lifecycle-governed system that can deny operational trust **before** physical failure occurs.

Phase IV performs a different function.

It formally introduces **Structural Governance Systems (SGS)** as a **new scientific class**, and positions SSB as its **first complete, executable instance**.

Phase IV does **not** introduce new equations, simulations, or validations.
It defines a missing layer in scientific reasoning itself.

11.2 Definition — Structural Governance System (SGS)

A **Structural Governance System (SGS)** is a deterministic system that:

- consumes outputs of a valid physical or mathematical model,
- **does not modify** those outputs,
- introduces an independent **permission layer** governing trust and reliance,
- may deny operational use even when the underlying model remains correct,
- operates without prediction, probability, or learning,
- is closed under re-evaluation.

Formal statement

An SGS answers the question:
"Should this result be trusted here, now, for operation?"

This question is **not addressed** by classical physics, control theory, or safety engineering.

11.3 What SGS Is Not (Boundary Clarification)

SGS must be distinguished from existing disciplines.

Discipline	Primary Function	Why SGS Is Not This
Classical physics	Computes forces, equilibria	SGS never computes forces
Control theory	Stabilizes or regulates behavior	SGS does not stabilize
Simulation	Predicts future states	SGS forbids prediction
Risk analysis	Assigns probabilities	SGS is non-probabilistic
Safety engineering	Applies margins & checklists	SGS is executable and lifecycle-aware
Machine learning	Learns from data	SGS has no learning

Conclusion:
SGS is not a refinement of existing fields.
It is a **new class operating above them**.

11.4 The Five Axioms of Structural Governance Systems

Any system claiming to be an SGS **must satisfy all five axioms**.

Axiom 1 — Non-Interference

An SGS must not alter, replace, or correct the governing physical or mathematical law.

Axiom 2 — Permission Primacy

Physical correctness does not imply operational permission.

Axiom 3 — Determinism

Identical inputs must always yield identical governance outcomes.

Axiom 4 — Lifecycle Awareness

Trust may degrade over time without violation of physical law.

Axiom 5 — Irreversibility of Denial

Re-evaluation must never increase permissiveness without an explicit structural reset.

SSB satisfies all five axioms.

11.5 SSB as the Canonical SGS Instance

Shunyaya Structural Buoyancy (SSB):

- accepts classical hydrostatic stability outputs (GM, GM_eff),
- never modifies buoyant force or stability equations,
- introduces structural posture `(m, a, s)` and lifecycle accumulation `s(t)`,
- deterministically governs trust via ALLOW / RESTRICT / DENY,
- denies reliance before physical failure,
- remains invariant under re-evaluation.

Formal classification

SSB is the **first complete, executable Structural Governance System (SGS)** applied to classical hydrostatics.

11.6 Why SGS Generalizes Beyond Buoyancy

Any domain that exhibits:

- delayed failure modes,
- operational reliance on correct physical outputs,
- cumulative degradation without immediate collapse,

is eligible for an SGS overlay.

Examples include (non-exhaustive):

- structural engineering,
- offshore and energy systems,
- medical device operation,
- autonomous systems,
- economic leverage and liquidity systems.

SSB demonstrates the class.
Other SGS instances may follow.

11.7 SGS Conformance Checklist (Normative for SGS Classification)

The following checklist defines the **minimum structural conditions** required for any system to be considered a valid **Structural Governance System (SGS)**.

This checklist is **normative for SGS classification**, not for certification.

A system that fails any mandatory item **must not** be described as an SGS.

A. Structural Separation (Mandatory)

☐ Classical physical or mathematical outputs are consumed **unchanged**
☐ The governance layer does **not** alter, correct, or override those outputs
☐ Collapse invariant holds: `phi((m, a, s)) = m`

B. Threshold Declaration Discipline (Mandatory)

☐ All thresholds are declared **prior to execution**
☐ Thresholds remain **immutable during execution**
☐ Thresholds are **auditable post-execution**
☐ No threshold is tuned, inferred, or optimized from outcomes

---

C. Determinism and Replay (Mandatory)

☐ Identical inputs yield identical governance outputs
☐ Re-execution reproduces identical denial boundaries
☐ No stochastic, probabilistic, or adaptive behavior exists
☐ No hidden state or learning is present

D. Lifecycle Awareness (Mandatory)

☐ Accumulated exposure is represented explicitly (`s(t)`)
☐ Structural degradation may occur without violation of governing law
☐ Governance decisions account for lifecycle accumulation, not only instantaneous state

---

E. Monotonicity and Irreversibility (Mandatory)

☐ Permissiveness is non-increasing within a lifecycle
☐ Once DENY is reached, return to ALLOW is impossible without explicit reset
☐ No spontaneous trust recovery is permitted

F. Non-Predictive Operation (Mandatory)

☐ The system does not predict failure timing
☐ The system does not assign probabilities
☐ The system does not simulate future trajectories
☐ Governance decisions concern **permission**, not outcomes

G. Ethical Boundary Enforcement (Mandatory)

☐ DENY is interpreted as withdrawal of reliance, not risk acceptance
☐ ABSTAIN blocks automation and requires human judgment
☐ Governance outputs are not used to justify extended operation after denial
☐ The system does not assign blame or causal certainty

SGS Classification Rule

A system qualifies as a **Structural Governance System (SGS) if and only if** all mandatory checklist items above are satisfied.

Shunyaya Structural Buoyancy (SSB) satisfies all checklist items and is therefore the **first complete, executable SGS instance**.

11.8 Why Phase IV Requires No New Validation

Phase IV introduces **classification**, not computation.

- Phase I validated logic.
- Phase II validated deterministic denial.
- Phase III validated operational envelopes.

Phase IV formalizes what those results *mean*.

No further testing is required to define a scientific class.

---

12. Phase IV — SGS Interface Contract and Compliance Profile

From validated subsystem to implementation-ready governance standard.

Phase IV formalizes Shunyaya Structural Buoyancy (SSB) as a **Structural Governance System (SGS)** — a reusable, deterministic trust layer that can be implemented consistently across domains without reinterpretation.

Phase IV does **not** introduce new physics, new dynamics, or new tuning.
It freezes **contracts, invariants, and interfaces** so SSB can be relied upon as an engineering standard.

12.1 Position of SSB Relative to Existing Standards

SSB is designed as a structural governance overlay above classical buoyancy and stability practice. It does not replace or modify existing hydrostatic or regulatory frameworks.

Classical stability standards answer whether a floating body satisfies physical stability requirements at a given instant. Examples include intact stability criteria, regulatory stability codes, and classification society requirements.

SSB operates at a different layer.

- Classical methods determine physical correctness.
- SSB determines whether continued operational reliance remains structurally admissible under accumulated exposure.

Accordingly:

- SSB does not certify stability.
- SSB does not replace statutory or classification requirements.

- SSB does not invalidate classical calculations.
- SSB evaluates governance permission using declared thresholds applied to lifecycle exposure.

The relationship may be summarized as:

classical hydrostatics → physical admissibility
SSB → reliance admissibility

A vessel or asset may remain class-compliant while SSB reaches DENY. This indicates exhaustion of declared structural trust rather than violation of physical laws.

12.2 SSB Compliance Statement (Template)

The following template defines how SSB may be declared within an operational or engineering context. This statement is informational and may be adapted to organizational policy.

SSB COMPLIANCE STATEMENT

This asset or operation applies Shunyaya Structural Buoyancy (SSB) as an operational governance overlay above classical hydrostatic and stability calculations.

1. Classical physics outputs remain unchanged and authoritative.
2. SSB does not predict failure timing and does not assign probabilities.
3. Thresholds are declared prior to execution and remain immutable during execution, including:

```
GM_safe
a_min
r_safe
s_max
```

(and where applicable) `s_warn_frac`

4. Governance outputs are interpreted only as operational permission states:

ALLOW_NORMAL
ALLOW_RESTRICTED_MONITOR
DENY_FINAL
ABSTAIN_HUMAN_REVIEW

5. A DENY state indicates withdrawal of operational reliance unless an explicit external structural reset is executed and recorded.
6. SSB does not replace statutory compliance, classification requirements, or engineering judgment. It provides a deterministic governance signal regarding continued reliance.

12.3 Operational Interpretation Boundary

SSB governance outputs must be interpreted within defined boundaries.

SSB does not:

- predict incidents,
- determine legal responsibility,
- replace investigation or inspection,
- override mandatory regulatory requirements.

SSB makes explicit a structural condition that is often implicit in operational practice: that continued reliance becomes inadmissible after sufficient accumulated exposure, even when instantaneous physical checks remain acceptable.

The purpose of SSB is therefore transparency and auditability of reliance decisions, not replacement of engineering authority.

12.4 SGS Definition (Formal)

A **Structural Governance System (SGS)** is defined as:

A deterministic decision layer that operates *above* classical laws, preserves all classical outputs unchanged, and governs whether reliance on those outputs is structurally admissible over time.

Core properties (mandatory):

- Collapse invariant preserved: classical outputs are never modified
- Deterministic execution
- Monotone permissiveness (no recovery without reset)
- Lifecycle-aware (accumulation is first-class)
- Non-predictive (no forecasting, no simulation)

SSB is the **first complete SGS instance**.

12.5 SGS Admissibility States (Frozen)

Every SGS **must** emit exactly one of the following states at each evaluation step:

- **ALLOW_NORMAL**
  Structural posture is healthy; unrestricted operation admissible.
- **ALLOW_RESTRICTED_MONITOR**
  Operation admissible with monitoring or procedural constraints.

- **DENY_FINAL**
  Structural trust exhausted; operation inadmissible regardless of classical correctness.
- **ABSTAIN_HUMAN_REVIEW**
  Required structural inputs missing, invalid, or undefined.

These states are **exclusive, deterministic, and irreversible within a run**.

12.6 SGS Reason Codes (Mandatory for Auditability)

Each non-ALLOW_NORMAL decision **must** carry one or more explicit reason codes.

Canonical SSB reason codes (minimum set):

- `NEGATIVE_EFFECTIVE_STABILITY`
  (`GM_eff <= 0`)
- `INSUFFICIENT_ALIGNMENT`
  (`a < a_min`)
- `STRUCTURAL_RESISTANCE_EXCEEDED`
  (`s >= s_max`)
- `STRUCTURAL_WARNING_THRESHOLD`
  (`s >= s_warn`)
- `INVALID_INPUTS`
  (NaN, missing, inconsistent geometry)

Reason codes are **evidence**, not explanation.
No heuristic interpretation is permitted.

12.7 SGS Monotonicity & Irreversibility Rules

All SGS implementations **must enforce**:

1. **No spontaneous recovery**
   Once DENY is reached, the system cannot return to ALLOW states without an explicit reset.
2. **Non-increasing permissiveness**
   Permissive states may degrade; they may never improve within the same lifecycle.
3. **Deterministic replay**
   Identical inputs must reproduce identical envelopes, boundaries, and counts.
4. **Parameter immutability**
   Thresholds are declared once per run and never tuned during execution.

These rules are **non-negotiable** for SGS compliance.

12.8 Phase IV Interface Contract (Canonical Output Schema)

Every SSB / SGS evaluation **must emit** rows conforming to the following minimal contract:

Per-step record

```
t,
GM_eff,
a,
r,
s,
phase2_status,
envelope_class,
reason_code
```

Run-level header (mandatory)

```
GM_safe,
a_min,
r_safe,
s_max,
s_warn,
disturbance_schedule_id,
geometry_id,
execution_hash
```

This contract guarantees:

- auditability
- cross-implementation comparability
- clean replay and verification
- legal defensibility

12.9 Optional Phase IV Validation — Coupled Stress Envelope Test

Objective
Validate that SGS envelopes remain deterministic and monotone under *simultaneous* degradation modes.

Test construction

- Increase `KG` (center of gravity drift)
- Accumulate `FSC` (free-surface effects)
- Increase displacement ∇
- Apply cyclic disturbance `delta(t)`

All schedules must be **declared, deterministic, and non-adaptive**.

Expected invariant outcomes

- Envelope transitions remain ordered:
  `ALLOW_NORMAL → ALLOW_RESTRICTED_MONITOR → DENY_FINAL`
- DENY always precedes classical instability
- No envelope widening under combined stressors
- Replay invariance holds

This test demonstrates **governance robustness**, not numerical sophistication.

---

13. Positioning SSB Relative to Control Theory and Safety Engineering

---

13.1 Control Theory Comparison

Control theory:

- acts *within* the system,
- modifies inputs to maintain stability,
- assumes continued operation is desirable.

SSB:

- acts *above* the system,
- never modifies inputs,
- may deny operation entirely.

Key distinction
Control theory stabilizes.
SSB governs permission.

They are complementary, not competing.

13.2 Safety Engineering Comparison

Safety engineering:

- relies on margins, procedures, redundancy,
- is often static or checklist-based,
- may not capture deterministic lifecycle erosion.

SSB:

- is executable,
- accumulates structural resistance over time,
- enforces irreversible denial when trust is exhausted.

SSB converts safety from *policy* into *deterministic governance*.

---

14. Journal-Ready Abstract (Phase IV Integrated)

Title
Structural Governance Systems: A Deterministic Trust Layer Above Classical Physics

Abstract
Classical physical laws determine whether systems are correct, stable, or balanced, but they do not govern whether such states should be trusted operationally over time. This work introduces Structural Governance Systems (SGS), a new scientific class that operates above physical law without modifying it, and governs trust through deterministic permission logic.

We present Shunyaya Structural Buoyancy (SSB) as the first complete, executable instance of an SGS. SSB introduces structural posture, lifecycle accumulation, and irreversible trust denial, allowing operational reliance to be denied even when classical buoyancy and stability remain positive. Across deterministic validation scenarios, SSB consistently denies trust before physical failure, without simulation, probabilistic assumptions, or tuning.

By formalizing governance as a first-class scientific concern, SGS fills a foundational gap between physical correctness and operational safety. This framework generalizes beyond buoyancy to any domain where delayed failure and cumulative degradation render correctness insufficient for trust.

---

15. Why This Matters

SSB enables capabilities not present in classical buoyancy analysis:

- early warning without prediction
- prevention without simulation
- governance without hindsight
- explanation of delayed failures after long apparent safety

SSB applies naturally to:

- naval architecture and vessel operation
- offshore platforms and floating infrastructure
- disaster-response and rescue systems
- biological and physiological buoyancy contexts

- economic and systemic “floating equilibria”

---

16. Conclusion

Shunyaya Structural Buoyancy does not challenge classical physics.
It completes it.

By introducing structural admissibility, SSB transforms buoyancy from a binary condition into a governed, observable, and ethically safer concept — one that knows when floating must prove it is safe.

APPENDIX A — Phase-II Canonical Validation Results

Deterministic Validation of Shunyaya Structural Buoyancy (SSB)
(Displacement, Free-Surface Accumulation, and Structural Time)

Canonical status
All results in this appendix are **Phase-II canonical** and were generated under the following guarantees:

- **No simulations**
- **No probabilistic assumptions**
- **No stochastic inputs**
- **No tuning between runs**
- **Deterministic execution and reproducibility**

Appendix A-0 — Common Definitions (Applies to All Phase-II Tests)

Classical relations (unchanged):

- `BM = I_T / ∇`
- `KM = KB + BM`
- `GM = KM - KG`

Effective stability margin used by SSB (unchanged):

- `GM_eff = GM - FSC` (single FSC case)
- `GM_eff = GM - FSC_total` (ladder case)

SSB governance (unchanged):

- `margin = GM_eff / GM_safe`
- `a = clamp01(margin)`

- `r = max(0, 1 - margin)`
- `s(t+1) = s(t) + max(0, r - r_safe)`

Decision rule (unchanged):

- **DENY** if `GM_eff <= 0`
- **DENY** if `a < a_min`
- **DENY** `if s >= s_max`
- **else ALLOW**

Appendix A-1 — Displacement Sweep Validation (∇-Sweep)

Objective

To evaluate whether classical positive stability (`GM > 0`) is sufficient for structural trust, and to test whether SSB introduces a deterministic safety buffer under increasing displacement.

The test varies displaced volume ∇ while holding geometry and mass properties fixed.

- No simulations
- No probabilistic assumptions
- No tuning between runs

Test Definition (Common)

Classical relations (unchanged):

- `BM = I_T / ∇`
- `KM = KB + BM`
- `GM = KM - KG`
- `GM_eff = GM - FSC`

SSB governance (unchanged):

- `margin = GM_eff / GM_safe`
- `a = clamp01(margin)`
- `r = max(0, 1 - margin)`
- `s(t+1) = s(t) + max(0, r - r_safe)`

Decision rule (unchanged):

- **DENY** if `GM_eff <= 0`
- **DENY** if `a < a_min`
- **DENY** `s >= s_max`
- **else ALLOW**

Case A — Baseline Configuration

Inputs

- `I_T = 3.6 m^4`
- `KB = 0.55 m`
- `KG = 0.90 m`
- `FSC = 0.00 m`
- `∇ sweep: 5.0 -> 12.0 (step 0.25)`

SSB thresholds

- `GM_safe = 0.15`
- `a_min = 0.70`
- `r_safe = 0.10`
- `s_max = 1.00`

Results summary

- **ALLOW:** 12 cases
- **DENY:** 17 cases
- **ABSTAIN:** 0 cases

Critical boundaries

- **First structural caution** (`GM_eff < GM_safe`):
  `∇ = 7.25`, `GM_eff ~= 0.1466`
- **First SSB DENY** (while `GM_eff` still positive):
  `∇ = 8.00`, `GM_eff = 0.1000`
- **First classical instability** (`GM_eff <= 0`):
  `∇ = 10.50`, `GM_eff ~= -0.0071`

Key observation
SSB denies operational trust **2.5 m^3 of displacement** before classical instability occurs, creating a deterministic safety buffer.

Case B — Stressed Configuration (Raised KG + FSC)

Inputs

- `I_T = 3.6 m^4`
- `KB = 0.55 m`
- `KG = 0.95 m`
- `FSC = 0.05 m`
- `∇ sweep: 5.0 -> 14.0 (step 0.25)`

SSB thresholds (unchanged)

- `GM_safe = 0.15`
- `a_min = 0.70`
- `r_safe = 0.10`
- `s_max = 1.00`

Results summary

- **ALLOW:** 6 cases
- **DENY:** 31 cases
- **ABSTAIN:** 0 cases

Critical boundaries

- **First structural caution** (`GM_eff <= GM_safe`):
  `∇ = 6.00`, `GM_eff = 0.1500`
- **First SSB DENY** (while `GM_eff` still positive):
  `∇ = 6.50`, `GM_eff ~= 0.1038`
- **First classical instability** (`GM_eff <= 0`):
  `∇ = 8.25`, `GM_eff ~= -0.0136`

Key observation
Under degraded conditions, the SSB denial boundary shifts earlier, maintaining a conservative safety margin without altering physics.

Cross-case structural insight

Across both runs:

1. Positive GM is necessary but not sufficient
2. SSB denial always precedes classical instability
3. The buffer widens under structural degradation
4. Behavior is monotonic, deterministic, and reproducible
5. No tuning was required between runs

Formal conclusion (Phase-II result)

The displacement sweep confirms that:

Buoyancy is not a binary fact.
It is a structurally governed permission.

SSB introduces a governance envelope that denies trust before physical failure — without modifying classical hydrostatics.

This validates SSB as:

- a trust governor, not a predictor
- a safety overlay, not a force model
- a Phase-II–ready Shunyaya subsystem

Appendix A-2 — Multi-Tank FSC Ladder Validation (Stepwise Free-Surface Accumulation)

Objective

To validate that SSB responds deterministically to incremental free-surface effects using a multi-tank ladder, and to test that trust is governed even when classical stability remains positive.

- No simulations
- No tuning between runs
- Deterministic accumulation only

Test Definition (Common)

Classical relations (unchanged):

- `BM = I_T / ∇`
- `KM = KB + BM`
- `GM = KM - KG`
- `FSC_total = sum(FSC_i)`
- `GM_eff = GM - FSC_total`

SSB governance (unchanged):

- `margin = GM_eff / GM_safe`
- `a = clamp01(margin)`
- `r = max(0, 1 - margin)`
- `s(t+1) = s(t) + max(0, r - r_safe)`

Decision rule (unchanged):

- **DENY** if `GM_eff <= 0`
- **DENY** if `a < a_min`
- **DENY** `s >= s_max`
- **else ALLOW**

Configuration (Both Runs)

Inputs

- `I_T = 3.6 m^4`
- `∇ = 8.0 m^3`
- `KB = 0.55 m`
- `KG = 0.90 m`

SSB thresholds

- `GM_safe = 0.15`
- `a_min = 0.70`
- `r_safe = 0.10`
- `s_max = 1.00`

Derived baseline (for clarity)

- `BM = I_T/∇ = 3.6/8.0 = 0.45`
- `KM = KB + BM = 0.55 + 0.45 = 1.00`
- `GM = KM - KG = 1.00 - 0.90 = 0.10`

Therefore at `FSC_total = 0`:

- `GM_eff = 0.10`
- `margin = GM_eff/GM_safe = 0.10/0.15 = 0.666666...`
- `a = 0.666666...` which is below `a_min = 0.70`

This means SSB denial is expected at step 0, even before any FSC increments.

Run A — Default Ladder

FSC ladder contributions (m):
`0.00, 0.04, 0.08, 0.12, 0.16, 0.20`

Result

- First DENY at `i = 0` with:
  - `FSC_total = 0.000000`
  - `GM_eff = 0.100000`
  - `a = 0.666667`
  - `r = 0.333333`
  - `s = 0.233333`

Run B — 3-Tank Ladder (Stop on Deny)

FSC ladder contributions (m):
`0.00, 0.03, 0.03, 0.05, 0.06, 0.08`

Result

- First DENY at `i = 0` with:
  - `FSC_total = 0.000000`
  - `GM_eff = 0.100000`
  - `a = 0.666667`
  - `r = 0.333333`
  - `s = 0.233333`

Phase-II-B conclusion

This ladder validation confirms:

1. SSB can deny trust even when `GM_eff > 0`
2. The denial is deterministic and threshold-driven (`a < a_min`), not tuned
3. The ladder formulation is correct (`FSC_total = sum(FSC_i)`)
4. The result demonstrates the SSB principle:
   "Buoyancy is not a fact; it is a permission that must earn trust."

Appendix A-3 — Cyclic Fatigue Validation (Deterministic s(t) Accumulation Under Disturbance)

Objective

To validate that SSB can govern continuous trust over time, by accumulating structural resistance `s(t)` under a deterministic disturbance schedule, and denying operation when accumulated resistance exceeds a declared limit — even if classical stability remains positive.

- No simulations
- No stochastic inputs
- No tuning between runs

Test Definition (Common)

Classical relations (unchanged):

- `BM = I_T / ∇`
- `KM = KB + BM`
- `GM = KM - KG`

Lifecycle law (deterministic test law):

- `GM_eff(t) = GM - FSC - delta(t)`

Square-wave disturbance schedule (deterministic):

- `delta(t) = amp` during ON phase
- `delta(t) = 0` during OFF phase
- ON fraction = `duty`
- cycle length = `period`

SSB governance (unchanged):

- `margin(t) = GM_eff(t) / GM_safe`
- `a(t) = clamp01(margin(t))`
- `r(t) = max(0, 1 - margin(t))`
- `s(t+1) = s(t) + max(0, r(t) - r_safe)`

Decision rule (unchanged):

- **DENY** if `GM_eff(t) <= 0`
- **DENY** if `a(t) < a_min`
- **DENY** `if s(t) >= s_max`
- **else ALLOW**

Run A — CYCLIC_BASE (Immediate Denial Under Worst-Case ON)

Inputs

- `I_T = 3.6`
- `∇ = 8.0`
- `KB = 0.55`
- `KG = 0.88`
- `FSC = 0.06`

Derived

- `BM = 3.6/8.0 = 0.45`
- `KM = 0.55 + 0.45 = 1.00`
- `GM = 1.00 - 0.88 = 0.12`

Disturbance

- `mode = square`
- `amp = 0.06`
- `period = 20`
- `duty = 0.35`

SSB thresholds

- `GM_safe = 0.15`
- `a_min = 0.70`
- `r_safe = 0.10`
- `s_max = 1.00`

Result
At `t = 0` (ON phase):

- `GM_eff(0) = 0.12 - 0.06 - 0.06 = 0.00`
- First DENY at `t = 0` because `GM_eff(0) <= 0`

This run demonstrates correct **hard-stop behavior** when worst-case disturbance consumes the stability margin.

Run B — FATIGUE_LATE_DENY (True Fatigue: ALLOW First, DENY Later via s(t))

Inputs

- `I_T = 3.6`
- `∇ = 8.0`
- `KB = 0.55`
- `KG = 0.80`
- `FSC = 0.03`

Derived

- `BM = 3.6/8.0 = 0.45`
- `KM = 0.55 + 0.45 = 1.00`
- `GM = 1.00 - 0.80 = 0.20`

Disturbance

- `mode = square`
- `amp = 0.05`
- `period = 20`
- `duty = 0.35`
- `T = 400`

SSB thresholds

- `GM_safe = 0.15`
- `a_min = 0.70`
- `r_safe = 0.10`
- `s_max = 1.00`

Key event (first denial)
First DENY at `t = 22` with:

- `delta(t) = 0.05`
- `GM_eff(t) = 0.12`
- `a(t) = 0.80`
- `r(t) = 0.20`
- `s(t) = 1.00`

Interpretation (strictly from the rule)
Denial occurs:

- not because `GM_eff(t)` becomes negative (it remains positive)
- not because `a(t)` drops below `a_min` (it remains above)

Denial occurs because accumulated resistance reaches the declared maximum.

Since:

- `s(t+1) = s(t) + max(0, r(t) - r_safe)`
- here `r(t) = 0.20` and `r_safe = 0.10`
- so each ON exposure adds `0.10` to `s`
- after enough exposures, `s` reaches `s_max = 1.00` → DENY

This is the intended Phase-II lifecycle result:
stable enough to float, but not safe enough to keep trusting indefinitely under recurring disturbance.

Phase-II-C conclusion

This cyclic fatigue validation confirms:

1. SSB supports structural time via deterministic resistance accumulation `s(t)`
2. SSB can deny operation even while classical stability remains positive (`GM_eff > 0`)
3. Denial can be driven by lifecycle fatigue (accumulated `s`) rather than instantaneous failure
4. Behavior is deterministic, reproducible, and threshold-governed (no tuning)

Unless explicitly stated otherwise, all relations, thresholds, and decision rules are unchanged across Appendix A.

Formal conclusion (Phase-II result)

SSB does not merely gate buoyancy at a point in time.
It governs whether buoyancy remains safe to trust across time.

Appendix B — Phase III Worked Operational Examples (SSB)

Operational Interpretation Without Prediction or Simulation

This appendix provides concrete, deterministic examples illustrating how **Phase III operationalization** of Shunyaya Structural Buoyancy (SSB) functions in practice.

All examples:

- use Phase-I definitions
- rely only on Phase-II validated behavior
- introduce **no new equations**
- include **no tuning, simulation, or forecasting**

The purpose is **interpretability**, not additional validation.

Appendix B-1 — Static Allowance vs Restricted Operation

Scenario
A vessel satisfies all Phase-II ALLOW conditions at the current time.

Inputs:

- `GM_eff = 0.22`
- `GM_safe = 0.15`
- `margin = 1.4667`
- `a = 1.0`
- `r = 0`
- `s = 0.12`
- `s_max = 1.00`

SSB Decision (Phase-II rule):
→ ALLOW

Phase-III Interpretation
Because:

- `a` is well above `a_min`
- `s` is far from `s_max`

Operational classification:

- **ALLOW — Normal Operation**

No restrictions are imposed.
No monitoring escalation is required.

Key Insight
Phase III does not weaken ALLOW.
It simply *qualifies* it.

Appendix B-2 — ALLOW with Structural Degradation (Restricted Envelope)

Scenario
The system remains ALLOW, but structural resistance has accumulated.

Inputs:

- `GM_eff = 0.18`
- `GM_safe = 0.15`
- `margin = 1.20`
- `a = 1.0`
- `r = 0`
- `s = 0.82`
- `s_max = 1.00`

SSB Decision:
→ ALLOW

Phase-III Interpretation
Although ALLOW is still valid:

- `s` is approaching `s_max`
- future disturbances may trigger denial

Operational classification:

- **ALLOW — Restricted / Monitor**

Permitted actions:

- continue operation
- reduce loading
- reduce speed
- shorten exposure duration
- increase inspection frequency

Prohibited actions:

- extending mission duration
- increasing load or disturbance

Key Insight
Phase III enables *preventive caution* without prediction.

Appendix B-3 — Trust Denial Without Physical Instability

Scenario
The vessel remains classically stable, but SSB denies trust.

Inputs:

- `GM_eff = 0.11` (positive)
- `GM_safe = 0.15`
- `margin = 0.733`
- `a = 0.733`
- `r = 0.267`
- `s = 1.05`
- `s_max = 1.00`

SSB Decision:
→ DENY

Reason:

- `s >= s_max`

Phase-III Interpretation
This is **not** a failure.
This is a **governance refusal**.

Operational meaning:

- the system may still float
- but must no longer be *trusted* for continued reliance

Permitted actions:

- controlled shutdown
- offloading
- stabilization
- recovery procedures

Prohibited actions:

- continued mission operation
- load increase
- exposure continuation

Key Insight
SSB refuses trust **before** physics fails — by design.

Appendix B-4 — ABSTAIN and Human Authority Boundary

Scenario
Required inputs are incomplete or invalid.

Examples:

- missing FSC data
- undefined GM_safe
- corrupted geometry input

SSB Decision:
→ ABSTAIN

Phase-III Interpretation
ABSTAIN:

- is not ALLOW
- is not DENY
- disables automated trust decisions

Operational requirement:

- human review
- data correction
- re-declaration of thresholds

Ethical Boundary
ABSTAIN cannot be overridden programmatically.

Key Insight
SSB explicitly knows when it does **not** know.

Appendix B-5 — Retrodictive Safety Interpretation (Post-Event Analysis)

Scenario
A vessel failure occurred at time `t_fail`.

SSB is re-evaluated using:

- published vessel parameters
- declared thresholds
- recorded disturbances

Observation
SSB denial occurred at:

- `t_deny < t_fail`

Interpretation
SSB does **not** claim:

- failure timing
- failure causality

SSB claims:

"Trust should have been denied at `t_deny`."

Key Insight
SSB reframes failure analysis as **trust overextension**, not prediction error.

Appendix B-6 — Structural Invariants Across Examples

Across all Phase-III examples:

1. No rule was altered
2. No threshold was tuned
3. No simulation was performed
4. No prediction was made
5. No denial was reversed
6. No permissiveness increased over time

SSB behavior remains:

- monotonic
- deterministic
- conservative
- ethically constrained

Appendix B — Closing Note

These worked examples demonstrate that Phase III:

- operationalizes SSB without modifying Phase I or II
- enables safer decision-making without foresight
- preserves classical physics while governing trust

SSB is therefore not only **correct** and **validated**,
but **usable**, **auditable**, and **deployment-ready**.

APPENDIX C — PHASE III OPERATIONAL ENVELOPE (STRUCTURAL CLASSIFICATION)

Appendix C.1 — Phase III Purpose (What Phase III Adds Beyond Phase II)

Phase II establishes that Shunyaya Structural Buoyancy (SSB) is deterministic and that **DENY** can occur even while `GM_eff > 0` — proving that *trust can fail before physics fails*.

Phase III adds the missing operational layer.

It converts deterministic Phase II outputs into an **operational envelope**:

- **ALLOW_NORMAL** — operate normally
- **ALLOW_RESTRICTED_MONITOR** — operate with restrictions and monitoring
- **DENY_FINAL** — do not operate

This is **not prediction**.
This is **structural policy classification** over deterministic results.

Appendix C.2 — Phase III Inputs (What the Envelope Classifier Consumes)

Phase III consumes a **deterministic Phase II time-series**, where each row includes (at minimum):

- `t` — time index / row index
- `GM_eff(t)` — effective stability margin
- `a(t)` — alignment / permission ratio
- `r(t)` — instantaneous risk
- `s(t)` — accumulated structural resistance
- `SSB_status(t)` — Phase II decision (`ALLOW` / `DENY`)

Phase III **does not modify** these values.
It **only classifies** them into an operational envelope.

Appendix C.3 — Phase III Invariants and Thresholds (Declared, Not Tuned)

Phase III operates using **declared envelope limits**:

- `a_min` — minimum admissible alignment
- `s_max` — maximum allowed accumulated resistance

- `s_warn` — early-warning threshold for restricted operation

Defined as:

- `s_warn = s_warn_frac * s_max`

Canonical Phase III values used in this run:

- `a_min = 0.70`
- `s_max = 1.00`
- `s_warn_frac = 0.80`
- therefore `s_warn = 0.80`

No tuning.
No run-to-run adjustment.

Appendix C.4 — Phase III Envelope Rules (Deterministic)

For each time-step `t`, the envelope is assigned as follows:

ABSTAIN_HUMAN_REVIEW
Return `ABSTAIN` if required inputs are missing or invalid.

DENY_FINAL
Return `DENY` if **any hard condition** holds:

- `GM_eff(t) <= 0`, **or**
- `a(t) < a_min`, **or**
- `s(t) >= s_max`

ALLOW_RESTRICTED_MONITOR
Return `RESTRICT` if not denied, but trust has entered a warning corridor:

- `s(t) >= s_warn`
  (equivalently `s(t) / s_max >= s_warn_frac`)

ALLOW_NORMAL
Return `ALLOW` otherwise.

Important:
Phase III **never overrides physics**.
It governs **operational trust** using already-computed structural observables.

Appendix C.5 — Canonical Phase III Result (Envelope Counts)

For the canonical fatigue run, Phase III produced:

- **ALLOW_NORMAL:** 20
- **ALLOW_RESTRICTED_MONITOR:** 2
- **DENY_FINAL:** 378
- **ABSTAIN_HUMAN_REVIEW:** 0

First envelope crossings:

- First **RESTRICT:** `row_index = 20`
- First **DENY:** `row_index = 22`
- First **ABSTAIN:** not reached

Structural interpretation (plain language):

- For the first **20** time-steps, operation is structurally admissible.
- At **time-step 20**, the system enters a **monitoring corridor** — still operable, but no longer healthy.
- At **time-step 22**, operation becomes structurally unsafe — **not because buoyancy vanished**, but because **trust was deterministically exhausted**.

Appendix C.6 — Worked Example (Audit-Friendly Walk-Through)

This example explains the envelope transition using **only Phase II rules** — no new data.

Step 1 — Phase II Fatigue Law (Unchanged)

Stability evolution:

```
GM_eff(t) = GM - FSC - delta(t)
```

Structural observables:

- `margin(t) = GM_eff(t) / GM_safe`
- `a(t) = clamp01(margin(t))`
- `r(t) = max(0, 1 - margin(t))`
- `s(t+1) = s(t) + max(0, r(t) - r_safe)`

Step 2 — Why RESTRICT Occurs Before DENY

`RESTRICT` is triggered when:

```
s(t) >= s_warn = 0.8 * s_max
```

This creates a **pre-denial corridor**:

- Not denied
- Not healthy enough for normal operation

This is the **structural yellow zone**.

Step 3 — Why DENY Occurs at `row_index = 22`

`DENY` is triggered when:

`s(t) >= s_max` (or any hard condition)

In this fatigue scenario, denial occurs even while:

- `GM_eff(t) > 0`
- `a(t) >= a_min`

Thus, denial is **lifecycle-driven**, not force-driven:

- The system remains physically stable
- But becomes operationally untrustworthy under recurring exposure

This is the **structural red zone**.

Appendix C.7 — Phase III Conclusion (Why This Is Phase-III-Level)

Phase III completes SSB as an **operational governor**, not merely a validator:

- **Phase I:** formalizes trust logic (no empirical data required)
- **Phase II:** validates deterministic denial before classical failure
- **Phase III:** adds executable operational envelopes
  (`ALLOW_NORMAL`, `ALLOW_RESTRICTED_MONITOR`, `DENY_FINAL`)

Final statement:

SSB now governs not only
“is it stable?”
but also:
“what operational posture is structurally permitted at this time?”

APPENDIX D — Illustrative Governance Schematic (Non-Quantitative)

This appendix is **illustrative only**.
It contains **no operational data, no simulations, and no quantitative inference**.

Its purpose is **conceptual clarification for readers**, not analysis.

D.1 Purpose of This Schematic

The schematic below illustrates the **relationship between classical buoyancy correctness and SSB trust governance** across an evaluation lifecycle.

It does **not** represent:

- measurements
- simulations
- physical timelines
- probabilities
- failure prediction

It exists solely to make visible a distinction that classical buoyancy theory does not express:

Correctness of floating ≠ permission to rely on floating.

D.2 Conceptual Lifecycle Ordering (Illustrative)

A floating system may pass through the following **structural states**:

Classical Stable (`GM_eff > 0`)
↓
SSB **ALLOW** — Normal Operation
↓
SSB **ALLOW** — Restricted / Monitor
↓
SSB **DENY** — Trust Withdrawn
↓
(Classical instability may or may not occur later)

Important ordering constraints:

- SSB denial may occur **while `GM_eff > 0`**
- SSB denial must **not** occur after classical instability
- SSB denial does **not** imply physical failure

D.3 Illustrative Governance State Progression (Visual Schematic)

Figure D.1 provides an illustrative, non-quantitative visualization of the governance lifecycle described above.

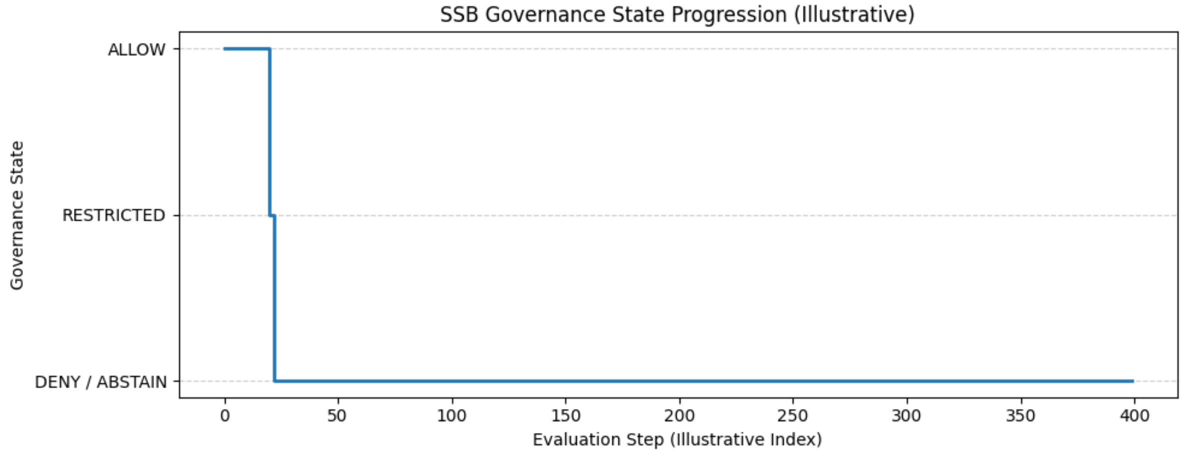

Figure D.1

The figure shows **discrete governance state transitions**:

- **ALLOW**
- **RESTRICTED**
- **DENY / ABSTAIN**

as a function of an **illustrative evaluation index**.

Key properties of the figure:

- The horizontal axis is **not time**
- The vertical axis is **categorical**, not numeric
- The step-wise structure indicates **governance transitions**, not degradation rates
- The extended DENY region illustrates **irreversibility of trust withdrawal within a lifecycle**

This figure is a **visual aid only**.
It does **not** participate in SSB computation or validation.

Figure D.2 — Physical Stability vs Structural Trust (Illustrative)

This figure visualizes the separation between **instantaneous physical stability** and **accumulated structural trust** within SSB using an actual Phase III run output.

The plot shows two run-derived sequences:

1. **Effective stability signal `GM_eff(t)`**
   This is the classical stability signal used by SSB **without alteration**. In this run, `GM_eff(t)` remains positive and nearly flat throughout, indicating that **no classical instability event** occurs within the plotted interval.
2. **Structural resistance accumulation `s(t)`**
   This represents lifecycle accumulation of resistance beyond declared tolerance. In this run, `s(t)` increases **monotonically** in a stepwise pattern from near zero to a substantially larger value by the end of the run, consistent with irreversible accumulation.

Vertical markers indicate the first occurrence of governance transition points in this run:

ALLOW_NORMAL → ALLOW_RESTRICTED_MONITOR → DENY_FINAL

In the plotted run, both **RESTRICTED** and **DENY** occur early while `GM_eff(t)` remains positive. This demonstrates the intended SSB behavior: **governance denial can occur due to exhausted structural trust even when classical stability remains valid**.

Interpretation limits (mandatory)

This illustration is explanatory only.

- **No quantitative inference is permitted** from the plotted magnitudes or spacing.
- The curves do not imply prediction of failure timing or incident occurrence.
- The figure does not reconstruct historical events.
- The illustration exists solely to explain the conceptual and operational distinction between classical stability `GM_eff(t)` and lifecycle admissibility represented by `s(t)`.

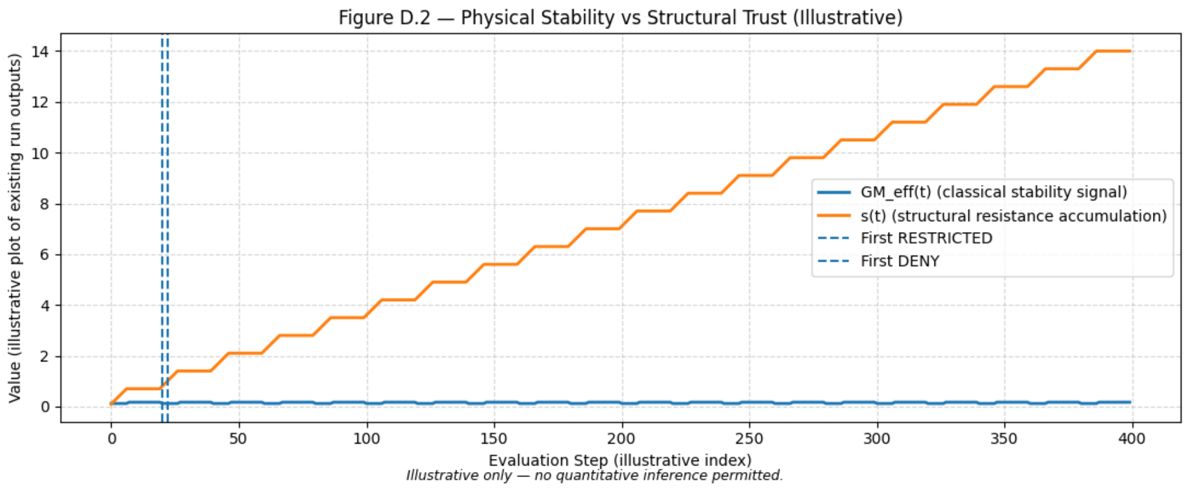

Figure D.2

Illustrative only. `GM_eff(t)` remains a preserved classical signal, while governance transitions arise from monotone accumulation `s(t)` and may occur while classical stability remains positive.

D.4 Structural State Interpretation

At all stages prior to classical instability:

- buoyant force remains valid
- hydrostatic equations remain correct
- stability calculations remain unchanged

What changes is **structural admissibility of reliance**, governed by SSB using:

- normalized alignment `a`
- accumulated resistance `s(t)`

Once SSB outputs **DENY**:

- the system may still float
- physics remains correct
- continued reliance becomes structurally unjustifiable

This intermediate state — **physically stable yet structurally denied** — is the **core contribution of SSB**.

D.5 What This Schematic Must NOT Be Used For

This schematic must **not** be used to:

- infer trends
- estimate timelines
- suggest degradation rates
- imply probabilities
- claim predictive capability

Any quantitative interpretation of this schematic is **invalid by definition**.

D.6 Why This Figure Is Illustrative and Not Analytical

SSB deliberately avoids analytical plots in core logic because plots invite:

- trend interpretation
- probabilistic inference
- predictive misreading

The figure in this appendix is **explicitly illustrative**, detached from computation, and included solely to communicate **structural ordering**, not magnitude or dynamics.

D.7 Mandatory Labeling Rule

Any reproduction of this schematic **must include the following label verbatim**:

"Illustrative only — no quantitative inference permitted."

Failure to include this label constitutes **misrepresentation of SSB**.

OMP